

Appendix A

Detailed Retrieval Case Histories

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Remote retrieval technologies have been demonstrated under hazardous conditions at numerous sites across the U.S. However, there is no reported experience with remote retrieval of transuranic (TRU) and radioactive buried waste, especially under conditions similar to those within the Subsurface Disposal Area (SDA) at the Idaho National Engineering and Environmental Laboratory (INEEL). Thus far, buried radioactive waste retrieval has been accomplished with manually operated construction equipment, some of which has been modified to protect the operator.

The following case studies summarize the work done to date with different excavator equipment to retrieve buried radioactive waste. Descriptions of the contamination control devices used in these studies are presented if available. In addition, Table A-1 compares the technology applications at each site.

Los Alamos Retrieval

The Area P Material Disposal Area (MDA-P) in Technical Area 16 (TA-16) is located in the southwest corner of the Los Alamos National Laboratory in New Mexico. The land has acquired by the Department of Army for the Manhattan Project in 1943.

The MDA-P was in operation from 1950 to 1984, receiving materials from the burning of high explosives (HE), HE-contaminated equipment and material, barium, nitrate, construction debris from Manhattan-era buildings, as well as empty drums, miscellaneous containers, trash, and vehicles. Chemicals of concern at this site include various types of HE, HE impurities and degradation products, uranium, metals (especially barium), volatile organic compounds, semivolatile organic compounds, and cyanide. Waste retrieval at the MDA-P is completed.

To mitigate the dangers of a detonation during the landfill excavation, all initial excavation operations were mandated to be performed remotely. Boissiere Engineering and Applied Robotics (BEAR) Inc. developed and deployed a Hybrid Remote Robotic Manipulation and Excavation System (HERMES) for the landfill excavation.

HERMES consisted of a 62,000-lb computer-controlled tracked excavator coupled with a hydraulic manipulator. The configuration allowed the excavator to remotely execute conventional excavation operations such as overburden and debris removal in the landfill. The excavator was controlled from a remote operator console that received and transmitted data to and from the system via multiple communication channels. Multiple on-board cameras were used to facilitate remote operations, including excavation and robot manipulation. Containment structures were not used—the primary threat to human health during construction was from external radiation exposure and explosive detonation (rather than from contamination spread like that of the SDA). These controls were adequate for operation, and the remote excavator successfully retrieved the buried waste.

Table A-1. Retrieval technologies implemented for case histories.

Technologies			Site Case History								Proposed			
Contamination Control	Pre-Treatment	Fernald	Maralinga	Calvert City	Rocky Flats	Sandia Chemical Waste Landfill	Sandia Classified Waste Landfill <small>Unknown to be completed in 2003</small>	Sandia Radioactive Waste Landfill	Initial Drum Retrieval	Los Alamos	Early Waste Retrieval	618.4 Burial Ground	618-10 Burial Ground <small>Perflin injection system</small>	WAG-7 Retrieval <small>VOC extraction</small>
	Dust Suppression	Water, Con Cover	Water, monitored wind direction		Water				Weather shield		Water	Water	Water	wetting agents
	Source Control													fogger absorbent material wetting agents
	Decontamination	Water, Truck Wash			HEPA Filter System	Power wash			Air support		HEPA filter system	Coupling agent	Wetting agents	strippable coatings
	Containment structures	UA			Tenting	Plastic sheet covering over pit Tent for separation and sorting area			Pedia Guard II Sealant Absorbent		Bonding Agent Covering Area Containment Fabric blanket Absorbent Rug	Fracking Tent	Spray on Coating Grout Inflatable building Plastic barrier sheets Vacuum systems Sealants Shelters (prefabricated bld) Fabric covered building	Spray on coating double containment moveable barriers air locks absorbent material wetting agents strippable coatings
Retrieval Equipment	Excavator	Excavator, dump trucks, back hoers, bull dozers	Scrapers and bull dozers with pressurized and sealed cabins and filtered air	Large track hoers with pressurized and sealed cabins and supplied air	Track mounted excavator	Excavator	Excavator	Excavator	Scraper	HERMES (hyperbaric remote ventilation and excavation system)	Earth Scraper	Gizzly Apparatus	Track Excavator	Manned Backhoe
					Back Hoe Front End Loader	Track Hoe Bucket Front End Loader	Back Hoe Robotic Arm on a Back Hoe	Track Hoe Robotic Arm on a Back Hoe	Bull Dozer Drott Excavator		Back Hoe	Excavator Bucket Toolless Excavation Bucket Front End Loader Track Hoe w/ thumb	Back Hoe	Numerous end-effectors
Physical Treatment	Sizing													dozer gantry crane
	Sorting	Sorting, crushing, shredding			Sorting	Mechanical Sorting Screen	Sorting Separating				Waste Compactor Hydraulic Cutter	Sorting		cutting, shredding sort soil from debris via end-effectors
Characterization	In situ character.													Soil cover for release
	Sample collection	Sample collection, lab analyses				Sample collection, on site lab								All treatment facility
Packaging	Non destruction analysis													TRU NDA at storage
	Container	Placed straight into n cars, boxed and drummed waste included into n car			55 gallon drums	55 gallon drums					Plastic bags	55 gallon drums		temp. in soil bags 55-gallon drums waste bins

Sandia Landfill

The Radioactive Waste Landfill (RWL) ER Site 1 and Chemical Disposal Pits (CDP) Environmental Restoration (ER) Site 3 are located in the eastern portion of Technical Area II (TA-II) at the Sandia National Laboratory in New Mexico.

From 1949 to 1959, three pits and three trenches in the RWL received low-level radioactive waste. The unlined RWL pits were approximately 12 ft wide by 20 ft long by 25 ft deep, with no leachate detection or collection systems. Waste material disposed in the RWL mainly consisted of solids such as weapons components, irradiated and neutron-activated material, neutron generator parts, irradiated material from nuclear rocket tests, radium-beryllium neutron sources, thermal batteries, radioactive sources, laboratory-generated waste, and low-level waste material from nuclear reactor studies. The weapons components and waste material contained depleted uranium, thorium, tritium, cobalt, cesium, americium, and plutonium.

Small amounts of liquid waste were also present in the RWL. Chemical waste material included lead, thermal batteries, and nitric acid. Additional reported disposals included a Sandia Pulsed Reactor and tritiated waste from booster cylinders.

Reportedly, most of the waste was not contained before disposal, and the pits and trenches were covered with native soil and capped with 3 ft of concrete. Allegedly, a separate facility received all radioactive waste after March 1959, but one item removed from the landfill was dated 1978, contradicting this assertion.

The CDP was in use throughout the late 1940s and 1950s for disposal of chemical waste. The disposal pit was approximately 10 ft by 30 ft wide with an unknown depth. Unlined pits were not constructed with leachate containment or monitoring devices, and there were no records maintained of the pit locations, types and volumes of chemicals disposed, procedure of disposal, excavation of pits, or the exact length of time the pits were used.

In June 1995, the RWL and CDP combined to form one landfill site. Records show that an estimated 11,110 ft³ of radioactive waste, with an estimated total activity of 2,847 curies, was buried in the landfill. This estimate does not include the native soil backfill.

In late 1996, voluntary remediation of the site commenced, as shown in the photograph of the excavation in progress in Figure A-1. The excavation removed roughly 9,400 yd³ of soil; the retrieved waste included mixed and radioactive debris and radioactive soil. The tools and methods applied to the retrieval action included an excavator and a trackhoe, and sprung containment structures for fire and wind protection were used on-site.

A robotic arm, camera, and radiological meter were attached to the end of the operated backhoe when operators handled unknown radioactive material, not to excavate the material but to determine the radioactive concentrations. Once the site conditions were known, the manually operated excavator retrieved the waste. The site is currently awaiting approval to be backfilled.



Figure A-1. Sandia Landfill excavation.

Rocky Flats Plant, Trench 1

Operations at the RFP where the Trench 1 (T-1) burial ground is located, were involved with plutonium, depleted uranium, enriched uranium, beryllium, and stainless steel operations. The plant manufactured triggers for use in nuclear weapons and produced purified plutonium. The main source of waste deposited at T-1 consisted of depleted uranium chips. A photograph of the trench is shown in Figure A-2.

Conventional excavation techniques were used to remove the soil, drums, debris, and contaminated soils at T-1 (Kaiser-Hill 1999). Excavation equipment consisted of a track-mounted excavator, backhoe, and/or front-end loader. When drums containing depleted uranium were handled, an excavator bucket equipped to minimize spark-potential was employed.

To minimize exposure, the drums were removed one at a time, and site controls were instituted for both intact and nonintact drums. Located immediately adjacent to the excavation area, standard fire prevention and suppression techniques for pyrophoric-depleted uranium chips stood ready for use. A temporary structure designed to shed snow and withstand high winds and hail in accordance with applicable building codes and standards (e.g., Sprung Instant Structure) provided a weather shelter and sealed environment for operators performing excavation and treatment operations. The structure was constructed of flame retardant materials, with secondary containment for spill control, and was equipped with a high-efficiency particulate air (HEPA) filter system to control potential airborne contaminants.

The proposed accelerated action entailed excavating drums that contained depleted uranium chips in lathe coolant, associated soils with radionuclide activity that met or exceeded action levels, and other waste and debris from T-1. Materials were initially segregated as they were removed from the trench, and further segregated for potential pyrophoric content. Depleted uranium chips were stabilized by encapsulation in mineral oil or soil to address their potential pyrophoricity before shipment for off-Site treatment. Associated radiological contaminated soils above action levels were excavated, treated if necessary, and staged for off-Site disposal.

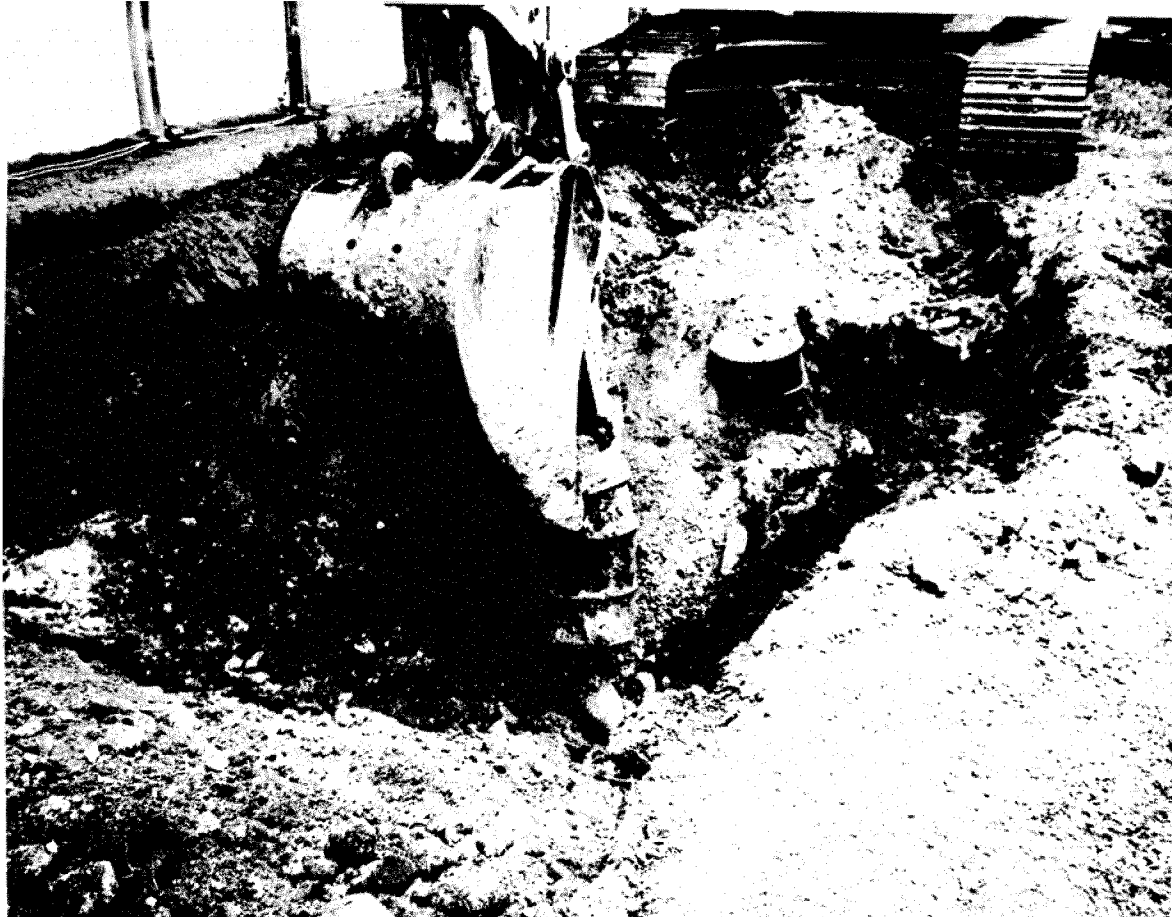


Figure A-2. Rocky Flats excavation.

Hanford 618-4

The 618-4 Burial Ground, located approximately 1 mile north of Richland, Washington, and 1,100 ft west of the Columbia River, is part of the remedial action activities at the Hanford 300 Area. Photographs of the excavation appear in Figures A-3 and A-4.

The 618-4 Burial Ground, a single disposal pit measuring approximately 105 ft by 525 ft, was believed to have operated as an official burial ground from 1955 through 1961. Test pit sample results identified uranium as the primary contaminant, consistent with available 300 Area process history, but little information exists to confirm the inventory and the source of waste deposited in the pit (BHI 1998). Investigations identified:

- Large amount of ferrous waste materials (based on geophysical surveys)
- Detectable concentrations of volatile organic compounds in soil gas samples
- Miscellaneous debris (e.g., contaminated pipe, scrap metal, salt-bath precipitate, rubber, pipe insulation, burnt wood, melted glass, asbestos, lead bricks) mixed with sand and gravel fill (observed during test pit excavation).

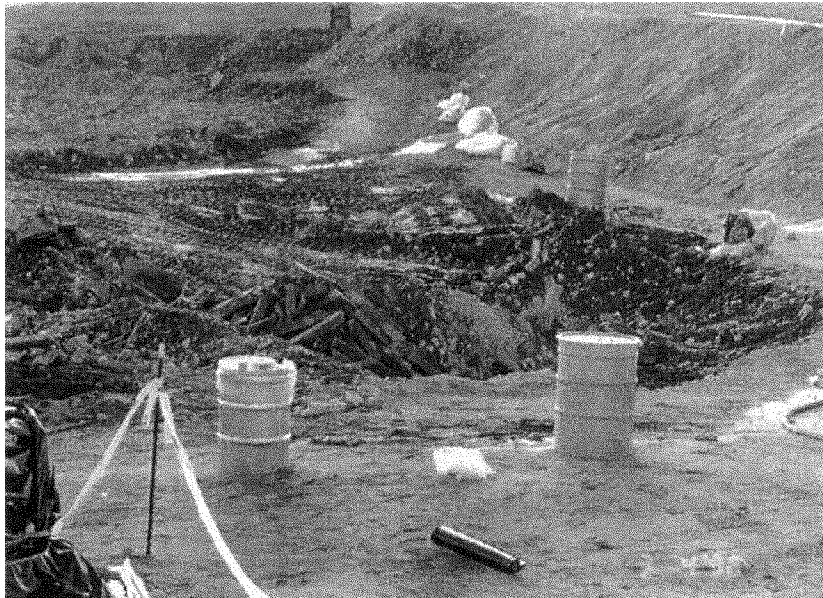


Figure A-3. Hanford 618-4 waste.



Figure A-4. Hanford 618-4 drums.

The 618-4 Burial Ground waste retrieval is not complete, as indicated by the photographs. Remedial action activities included removing the cover (topsoil and overburden) materials and retrieving the buried waste (BIII 1998).

A large number of drums were excavated from a central portion of the burial ground before activities ceased. To provide dust control during the period of inactivity, a crusting agent was applied to all of the soil surfaces and stockpiles (i.e., lead-contaminated soil, barium-contaminated soil, and lead debris) within the burial ground. Dust suppression during work operations typically involved applying water to the excavation areas using overland piping and a water truck. Efforts were made to minimize the amount of water necessary to maintain dust control and prevent the formation of puddles on applied surfaces.

A grizzly apparatus was initially used to sort waste material during the excavation process, but a field demonstration showed that alternate sorting methods were more effective and efficient.

The excavation employed a large excavator/bucket and a toothless (straight-edged) excavation bucket. The large excavator/bucket combination generally excavated material at a rate that exceeded the front-end loader capacity to fill haul containers. This enabled stockpiles to be made and screened before the load operation, and further permitted release/hold determinations to be made on each stockpile without affecting productivity. The toothless excavation bucket worked well to reduce the chances of tearing or puncturing anomalous waste items and containers. Additional excavation equipment included a John Deere front-end loader and trackhoe excavator with a thumb.

The presence of large quantities of anomalous waste materials postponed the remediation project. Equipment and personnel were demobilized from the site pending the disposition of the anomalous waste, and the excavation operations moved to another disposal site in May 1998. Demobilization was completed on May 5, 1998. Partial remediation of the 618-4 Burial Ground was performed safely without any lost-time injuries, though the cost of remediation was significantly greater than the original projection. The cost to complete the project was estimated at \$1.9 M—approximately \$3.04 M was spent to excavate 42% of the material projected in the initial design.

The primary lesson learned was that the project team had not anticipated the quantity and/or type of anomalous waste materials that were unearthed. A secondary lesson learned involved the inefficiency of the grizzly apparatus originally selected to sort waste material during the excavation process. Production time was also slowed when remediation of the burial ground was suspended on two occasions. The unexpected excavation of anomalous liquid waste material with unknown chemical hazards prompted the first suspension. On the second occasion, high winds that prevented the appropriate control of dust stopped excavation activities.

Fernald Waste Pits

The Fernald Environmental Management Project is a former uranium processing facility undergoing environmental remediation. The plant was in operation from 1951 to 1989. The 1,050-acre site is located about 18 miles northwest of Cincinnati, Ohio. Early in the cleanup process, management divided the site into five sections, known as operable units, to organize cleanup planning efforts and address site contamination. The operable units were divided based on physical location on-site and the potential for similar technologies to be used during cleanup. The operable units are the Waste Pits Remedial Action Project, On-Site Disposal Facility and Soil Characterization and Excavation Project, Decontamination and Dismantlement, Silos Project, and Aquifer Restoration and Wastewater Project.

The Fernald Waste Pits Remedial Action Project is part of Operable Unit 1. The 37-acre waste pit area in the northwest portion of the site includes six waste pits, a burn pit, clearwell, miscellaneous structures, facilities, and soil. The pits range in size from 1 to 5 acres and vary in depth from 10 to 40 ft. The waste pit area contains approximately 1 million tons of low-level radioactive waste from Fernald's uranium production operations. The waste contains uranium, thorium, and other contaminants.

On March 1, 1995, DOE and EPA signed a Record of Decision identifying the cleanup plan for the project. In 1999, the Waste Pits Project team initiated waste pit excavation. Soil was excavated with excavators, backhoes, and bulldozers. The excavated soil was then sampled and screened and moisture content and radiological levels were determined to decide if the waste needed to be treated. If treatable, the material was blended or treated using two indirect thermal dryers to remove the excess moisture. Excessively moist excavated soil could not be shipped to the commercial disposal facility, Envirocare, without treatment. Typically, most of the waste pit material did not require treatment and could be loaded directly into gondola railcars and shipped to Envirocare in Clive, Utah.

By the close of 2000, the project excavated approximately 30 % of waste from Pits 1 and 3 and shipped 32 railcars containing 194,000 tons of material to Envirocare. The Waste Pits Project is scheduled to complete waste excavation, processing, and railcar loading operation in 2004, and decontamination/dismantlement of equipment and facilities in 2005.

INEEL Solid Radioactive Waste Retrieval Test

During 1971 and 1972, a Solid Waste Radioactive Retrieval Test was performed on waste stored in Pits 2, 5, 10, and 11 in the SDA at the INEEL (Thompson 1972). The purpose of the test was to determine the condition of the waste and waste containers, the extent of plutonium migration in soil, the techniques required to minimize the spread of contamination, and from that information, determine the costs of retrieval.

Pit 2 was selected for the test portion that evaluated relatively old and stacked drums. Six barrels considered to be in the poorest condition (compared to those in other pits) were removed from the pit.

Pit 5 was selected for the portion of the test that determines the effect of the aging process on dumped drums. One barrel of Rocky Flats waste from Pit 10 also was targeted for retrieval, but was never excavated because of the random condition of the barrels that resulted from dumping.

Pit 11 was selected for the retrieval test to provide the best possible representative sampling of stacked waste containers that were in good condition. Two barrels of Rocky Flats waste also were targeted for retrieval, but only one barrel could be found, probably because of the complicated circumstances that existed at the time the barrel was buried. Five other barrels were removed without complication. These barrels had been stacked and exhibited low radiation levels, which contributed to the ease of their removal.

Excavation equipment included a backhoe with a bucket for dirt removal, a road grader, and a bulldozer with earth scraper for large volume dirt removal. A crane or backhoe with a standard barrel chain-lifting device lifted and removed barrels from the excavation. The crane offered some advantages over the backhoe, allowing for the use of multiple chain-lifting devices and permitting a larger area to be covered.

The nature of the waste, however, greatly complicated the retrieval and slowed digging operations. The discovery of many seriously damaged barrels necessitated hand digging and lifting. Therefore,

during this test, hand digging was used extensively in conjunction with a backhoe to prevent rupturing of drums. Barrels damaged by equipment and ring closures that were hooked by the backhoe further slowed the retrieval efforts. Leaking sludge was also troublesome at the excavation, requiring surveys, contamination control measures, and repackaging before movement.

During Pit 5 retrieval, several filters exhibited radiation levels of 20 mR/hr at 3 ft away. As handling equipment was deemed inadequate to contain potential contamination spread and prevent unnecessary exposure to personnel, the filters were left in place. At Pit 2, a sludge drum was left in the pit because it was leaking a clear liquid.

Contamination control measures applied to this retrieval included plastic sheeting over excavated sites, the application of water to control dust, and a tent. Initial excavations were conducted in wind speeds of 10 mph or less. The hot cell operation was conducted under a sealed plastic tent in conjunction with the use of HEPA filters. Protective equipment included full protective clothing, full face masks, cotton overalls, plastic booties, latex boots, cotton hoods, gloves, and dust respirators. The respirators and frequent changes of protective clothing made working conditions difficult.

The test concluded that, given the large quantities of material to be retrieved, mass excavation techniques should be studied. The study recognized that the main problem inherent in mass techniques is achieving contamination control in areas where cardboard cartons and wooden boxes are buried and interspersed with barrels.

INEEL Initial Drum Removal

In 1974, the Initial Drum Retrieval (IDR) program was established for the primary purpose of demonstrating the safe retrieval, repackaging, and interim storage placement of drums containing TRU waste buried at INEEL (EG&G 1978a). The program followed the Solid Waste Radioactive Retrieval Test, and was limited to a portion of Pits 11 and 12 to avoid areas where drums were in poor condition. The pits contained radioactive waste in stacked drums that are included in the current scope of the SDA Feasibility Study.

The waste was retrieved with a scraper and/or dozer to remove the soil overburden to within 45 cm of the buried waste. The remaining soil overburden was removed with a Drott excavator, which was also used to remove drums and soil from the pit until a working face was formed. A photograph of the IDR site is shown in Figure A-5.

The drums were removed from the stacks, rigged out of the pit, and removed to a separate area for surveying and packaging. Breached drums were wrapped in plastic and placed in DOT 7A metal boxes. Drums with free liquids were placed over a drip pan containing absorbent material, then wrapped in plastic and boxed once the liquid was expelled. About 6% of the drums exhibited external alpha contamination up to 120,000 counts per minute (cpm). Roughly 155 drums contained free liquids with alpha contamination up to 40,000 cpm. Radiation levels on the drums were less than 10 mR/hr, with the highest reading at 120 mR/hr. Workers wore full sets of anticontamination clothing—coveralls, shoe covers, gloves, hard hat, and safety glasses—and carried respirators in case of an airborne release, though the respirators were never needed or used.

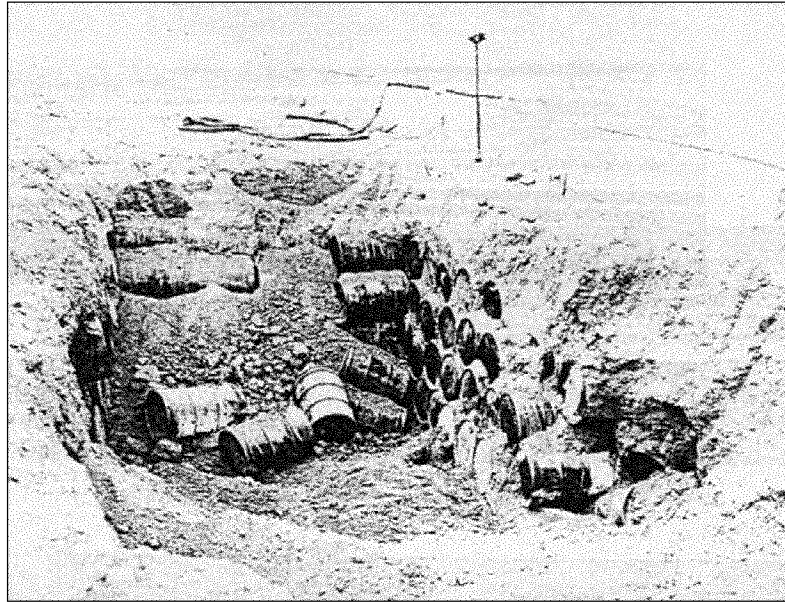


Figure A-5. IDR retrieval effort.

After removal techniques were optimized, these operations retrieved an average of 750 drums per month. Contamination controls included an air support weather shield (a reinforced fabric structure) over the work area. Cargo containers, floors, and the area extending 30 cm up the sidewalls were waterproofed with a sealant and absorbent material. The sealant and absorbent material precluded the spread of contaminated water from the cargo container in the event drums in the cargo container leaked.

The initial drum retrieval of Pit 11 was complete on June 20, 1977; Pit 12 was completed on June 12, 1978. The efforts safely retrieved 20,262 drums at a total cost of \$1,614,820. Overall, the retrieval was successful, with no serious injuries of personnel and no traces of contamination spread into the environment.

The report concluded that drums stacked in an orderly fashion and buried in the ground for less than 10 years could be retrieved in a manner similar to that of the IDR. However, the types of waste within the SDA are not similar to most of the waste in the retrieval test (stacked drums versus dumped loose drums, boxes, tanks, and debris). Consequently, current health and safety standards would not allow this type of waste handling.

Probing performed at Pit 6 indicated that the waste was intermixed drums, plywood boxes, and loose waste with removable alpha contamination up to 1,000,000 cpm, and the IDR report concluded that "the levels of loose alpha contamination are not conducive to IDR type operations." Similarly, the report probed waste in Pit 9 and concluded that "the condition of intermixed waste creates a high risk of contamination spread for IDR operations." The same conclusion was drawn for Pit 10 and the further pursuit of the IDR program was not recommended.

INEEL Early Waste Retrieval

Following the IDR test, the Early Waste Retrieval (EWR) project was implemented in November 1974 to retrieve the oldest of the buried waste at the SDA, which lies in Pits 1 and 2 (EG&G 1978; EG&G 1979). Both pits contain TRU and mixed fission product waste in containers that were stacked in an orderly fashion.

All retrieval activities for EWR were performed inside of an Operating Area Confinement (OAC). The OAC was a self-supporting metal building constructed of lightweight metal panels that prevented the spread of contamination to the environment and provided operational safety to personnel. An air-supported reinforced fabric structure designed to withstand wind and snow provided weather protection for the OAC, while a propane-fired furnace supplied heat to allow for an all-weather operation. The exhausted air was filtered through a HEPA filter and constantly monitored to detect any airborne activity during retrieval operations. Retrieval personnel wore full anticontamination clothing and a totally enclosed bubble suit with fresh air supply.

The excavation efforts removed the overburden with an earth scraper to within 45 cm of the buried waste. After the OAC was in position, a backhoe was placed inside and used to remove the remaining soil cover. Any remaining soil around the waste containers was carefully removed by manual labor. Available photographs of the buried drums uncovered during the EWR project show the retrieved waste containers in various stages of deterioration.

Removable alpha contamination was measured up to 2,000,000 cpm. All loose waste was removed by hand or shovel and placed into large plastic bags, which were taped shut and removed from the excavation when full. Drums, removed with vertical lift slings attached to the bucket of a backhoe, were placed into bags that were also taped shut. About one-third of operating time was spent packaging the waste. A waste compactor was procured to compact waste generated during the excavation, and a hydraulic cutter was used to size some retrieved items.

As the retrieval progressed, dust and loss of liquid from drums became major problems. Several contamination control measures were applied to mitigate the problem. A soil stabilization blanket that provided a strong fabric resistant to tear, chemicals, temperature changes, and moisture was used. The fabric prevented the migration of particles larger than 5 microns in size, which reduced the amount of contamination to the underlying soil. An additional oil absorbent rug was placed under the fabric for absorption of any liquid that may have passed through the fabric blanket. A combination of water and a bonding agent was used to control dust, and plastic strip curtains were installed to control air flow.

This retrieval effort handled and repackaged a total of 170.6 m³ of retrieved waste, contaminated soil, and waste generated from retrieval operations without spreading any contamination to the environment. The total cost for the project was \$1,202,705.

The experience gained from retrieval operations supports the concept of using mechanized retrieval equipment to obtain the retrieval rates necessary for possible production-scale retrieval. The project concluded that the retrieval equipment should be electronically operated rather than manually operated, and that retrieval personnel should be isolated as much as possible from waste to minimize personnel hazards and risks during retrieval, though the personnel on this project performed the hand retrieval. In addition, further studies and tests were recommended for sizing odd-shaped and large items.

1.1 Maralinga Rehabilitation Project

Maralinga is located in the southern Australian Outback near the edge of the Great Victorian Desert. From 1955 to 1963, nuclear weapons development trials were conducted. These trials included seven “major nuclear trials” involving atomic explosions and numerous “minor trials” designed to investigate the performances of various components of a nuclear device, which dispersed radioactive materials over small areas (Australian Department of Health and Ageing, 2001). Radioactive and nonradioactive waste was buried in burial pits located at Maralinga.

The area within and surrounding Maralinga was highly contaminated with a variety of radioactive materials, activation products, and fused sand (containing trapped radioactive materials). Today, the principal neutron activation products remaining in the soil are cobalt-60 and europium-152, and the principal remaining fallout components are strontium-90, cesium-137, and europium-155. There are also other portions of the site (Taranki, Wewak, TM100/101, Kuli, TM50, and other minor trial areas) that are highly contaminated with plutonium, beryllium, or uranium (or a combination of all three), all of which pose inhalation hazards. Of these highly contaminated sites, Taranki is the most contaminated,, primarily due to the 22 kg of plutonium that was explosively dispersed in a sector of several hundred hectares. Uranium-235 and beryllium were also dispersed in the trials performed at Taranki (ARPANSA, 2001a).

Many of the minor trial areas have already been sufficiently cleaned up or the radioactive materials had sufficiently short half-lives that they are no longer detectable. However, major trial areas and areas mentioned above as highly contaminated with plutonium, uranium, or beryllium required remediation.

To address the need for remediation, the Maralinga Rehabilitation Project was implemented (ARPANSA, 2001b). From 1996 to 2000, remediation at the Project primarily consisted of scraping up the contaminated soil and burying it at depth on-site. The top 1 ft of surface soil was removed and buried in trenches.

Due to extreme inhalation hazards associated with plutonium and the associated americium, uranium, and beryllium, modifications were made to the cabin and engine compartments of the soil removal and monitoring equipment. This equipment included scrapers and bulldozers for soil removal and jeeps for radiological surveys. The cabins were modified to allow operators to work in sealed and pressurized cabins, with filtered air intakes and extracts and minimal personal protective equipment (PPE). HEPA filters supplied clean air to the cabin and the engine compartments. There were provisions for emergency escape that proved successful during an engine failure caused by extreme heat, which forced an emergency evacuation. All personnel were safely evacuated (phone conversations with Dan Glenn 12/11/2001 and Bill Borden 12/12/2001, both CH2MHILL consultants who were involved in the project).

In addition to the cabin modifications, soils were kept moist and wind direction was monitored to keep contamination under control. These contamination controls, combined with careful work habits, were found to be very effective at this site. Work was completed successfully without any instances of plutonium migration.

Calvert City

In the mid- to late-1980s, BF Goodrich performed soil and sludge remediation of pits containing vinyl chloride as the main chemical of concern for the Calvert City Project in Kentucky (Davis-Smith 2001^a). Due to the hazardous characteristics of vinyl chloride, the excavation equipment (large trackhoes) was modified to provide better protection to the operators. This modification included sealing and pressurizing the cabins and supplying them with air from tanks attached to the equipment. HEPA filtration was not applicable in this situation because vinyl chloride quickly clogs filters. In addition to the air that supplied the cabins, operators were on separate supplied air lines and were in Level A PPE. The

a. Davis-Smith, 2001. Telephone conversation with Clay Morgan Davis/CH2MHILL at Separation Pilot Research Unit, New York, December 12, 2001.

air inside of the cab also was monitored to ensure a clean and safe environment. The equipment performed the required function and the operators were kept safe. Further details of this project are not available at this time due to the length of time since the project was implemented.

INEEL Full-Scale Design to Retrieve Waste at the SDA

In the late 1980s, a group of EG&G and DOE-ID personnel prepared a design for retrieval of Pit 9 (Schofield 2001). The retrieval structure consisted of a primary and secondary containment with the control room located in a separate auxiliary building. The primary containment was further divided into smaller areas by hanging curtains to reduce the size of the excavation area and to better control the spread of contamination. The HVAC design placed the primary containment at negative pressure to the secondary containment, whereby the air flow was directed up the face to HEPAs located directly above the dig face. The excavator was to be remote controlled with associated monitoring equipment attached.

Waste was to be retrieved, ground up, and mixed with burden and interstitial soils as the dig face progressed down the pit. The composite soil-waste was then transported to a hopper and placed in B-25 bins for segregation, characterization, and treatment. Intact drums were to be overpacked into larger containers at the hopper station. Higher activity sources were to be shielded and dealt with on a case-by-case basis. Larger metallic pieces (e.g. trucks, vessels, cranes, etc.) were to be left in place. Decontamination activities were completed on a routine cycle to maintain contamination at minimal levels.

Funding was pulled after approximately 2 to 3 years. At that time the project was in the preliminary design phase and the project ended.

INEEL Pit 9 Design

The three stage OU7-10 plan (INEEL 2000) was developed to remediate 200 yd³ of buried waste in Pit 9 for treatability tests at the SDA to meet the objectives of the Record of Decision Declaration for Pit 9 at the Radioactive Waste Management Complex (RWMC) SDA at INEEL (Valentich 1993). This design project is currently being reviewed and modified. For this project, the three stages included:

1. Stage I: Subsurface exploration to obtain material for bench-scale treatability studies and to allow for material characterization
2. Stage II: Limited retrieval/excavation in select areas of Pit 9 to obtain materials for pilot-scale treatability studies, in situ and ex situ treatment tests, and characterization of the waste and soils
3. Stage III: Full-scale remediation.

Stage I employed nonintrusive downhole logging (essentially a casing equipped with inner sampling equipment that collects no material but is placed within the waste) to locate areas of concentrated TRU waste in the area to be excavated in Stage II. Completed for a total cost of \$12 million, this stage of the project was considered successful because historical records and the results from the characterization coincided.^b Future characterization conducted with the logging tool will cost significantly less because evaluation and planning have been completed. The program is now in the field and operating.

b. McConnel, C., Telephone communication with Kira Sykes, March 28, 2001.

Stage II was taken to the design phase; EPA and the State of Idaho received a 90% complete design package in June of 2000. The retrieval system included the following performance characteristics:

1. Overburden will be removed to expose the waste.
2. Waste with TRU constituents less than or equal to 10 nCi/g containing 1,1,1-trichloroethane, trichloroethylene, perchloroethylene, and carbon tetrachloride will be removed.
3. The reactor vessel and steel vault will not be removed.
4. Waste with TRU constituents less than or equal to 10 nCi/g may remain in the pit.
5. Contaminated underburden will be removed.
6. Waste with TRU concentrations greater than 10 nCi/g will be treated according to the Record of Decision:
 - a. Waste to be returned to Pit 9 will be treated to remove hazardous components.
 - b. Treatment residuals with TRU concentrations greater than 10 nCi/g that are to be disposed in sites subject to LDRs will be treated to the levels specified in the ROD.
 - c. On-site treatment of materials containing TRU constituents greater than 10 nCi/g will not produce residuals with TRU concentrations between 10 nCi/g and 100 nCi/g.
7. Clean soil will be returned to the pit.
8. Low-level waste (less than or equal to 100 nCi/g for TRUs) will be either returned to Pit 9 following treatment or managed according to the Record of Decision.
9. Mixed low-level waste will be stored on-site if TRU concentrations are less than 100 nCi/g and LDRs are not met.
10. TRUs will be packaged for disposal at WIPP, but stored on-Site until receiving WIPP acceptance.

Because this design project involved a treatability test rather than a retrieval effort (with a goal of risk reduction), the design requirements for returning waste back into the pit may be modified if the design was applied to a full-scale retrieval. Additionally, provisions for retrieval of large debris would be included.

These performance characteristics resulted in a number of considerations for implementability in the system design:

- The retrieval facility will house equipment that can retrieve belowgrade waste containing TRU, low-level, mixed, and hazardous material
- The retrieval equipment will retrieve both intact and deteriorated waste containers
- The retrieval facility will have double confinement and may be a modular structure

- All the Stage II facilities and equipment will be relocatable for completion of Stage II operations and functions
- Retrieval equipment will be remotely operated for human factors.
- Individual worker radiation dose shall be less than 5 rem per year.

To date, the cost of performing this portion of Stage II is more than \$15 M and the project is now in a review cycle.^c The design package for this small-scale retrieval is comprehensive and includes design elements for 10 systems (structures, closure facilities, storage buildings, shoring, utilities, material handling and vacuum centers, secondary footings, data management, instrumentation, and equipment). The design project documentation comprises 27 binders that include plans, specifications, engineering design files, trade studies, data quality objectives, sampling plans, system requirements, functional requirements, safety requirements, reliability studies, performance requirements, schedules, costs, etc. The design package for a full-scale retrieval would be at least this exhaustive, and would add designs for treatment, packaging, transportation, and disposal systems.

The estimate to complete Stage II through retrieval and storage was \$117.5 M, which includes the retrieval and storage of the material, but does not include potentially significant costs associated with characterization, treatment, or disposal. This stage is scheduled to be completed in 2009 (DOE 2000).

Though the Pit 9 design is not directly applicable to a full-scale retrieval action at the SDA (modifications and additional facilities would have to be added), a significant amount of knowledge was gained concerning the design of a retrieval system in a TRU, hazardous, and pyrophoric environment. Many of the facilities (such as storage facilities) and engineering evaluations (such as reliability of equipment) are directly applicable. Key functional requirements that resulted from this process give light to the magnitude of the issues associated with removing these types of buried waste.

The implementation of this project would provide valuable information on the effectiveness, implementability, and cost of full-scale retrieval of the SDA. However, the DOE currently does not have the funding to implement this project, and it is not known when Stage II will be completed.

c. McConnel, C., Telephone communication with Kira Sykes, March 28, 2001.

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d. This web site was not available in December 2002 (information has been deleted or address has changed).